

*The Prospects and Challenges of Bio Ethanol Production from Molasses in the  
Ethiopian Sugar Industry* Girma A  
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# PROJECT REPORT

On

Prospects and Challenges of Bio Ethanol Production  
from Molasses in the Ethiopian Sugar Industry

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## **CHAPTER ONE**

### **2. INTRODUCTION**

#### **2.1. *Research Problem***

Production and use of bio-fuels for transport fuel has recently attracted significant attention worldwide. This is mainly due to the escalation of petroleum prices coupled with a shortage of foreign currency reserves and their reduced carbon emissions compared with fossil fuels. These factors and the increasing energy demand for transportation to keep the pace of economic development are alerting many countries, including Ethiopia, to find alternative energy sources for their security of energy supply.

In order to ensure Ethiopia's continued development program and the national fuel security, it is important to increase the production and utilization of renewable fuels. Substituting the demand for fossil fuel by locally produced fuels such as bio-ethanol and bio-diesel is paramount importance for the country's economic use of scarce energy resources. The Ethiopian bio-fuel development and utilization strategy has been designed based on this broad objective (Ministry of Water & Energy, 2010).

To realize the above strategic objective, the country is pursuing bio-ethanol development program. The Ethiopian Sugar Industry is responsible for the implementation of this strategic objective by producing bio-ethanol from molasses. In this regard, the gross available

potential land for sugarcane plantation to be used as feedstock for sugar extraction and eventually for bio-ethanol production from molasses is about 700,000 hectares, which offers a potential to produce above 1 billion liters of bio ethanol (Ministry of Water & Energy, 2010).

The production and use of bio-fuels has been justified by high oil prices, geo-political instability in those countries that hold most of the proven oil reserves as well as environmental concerns such as climate change or the improvement of air quality in metropolitan areas (Hazell and Pachauri, 2006). Bio-fuels production and use also poses challenges and risks including potential land use conflicts, environmental degradation risks, heightened concerns about food security and water conservation.

According to the bio-fuel development strategic plan of the country, up to the end of the fiscal year 2014/2015, the total bio-ethanol production and supply will reach 181.6 million liters (Ministry of Water & Energy, 2010). This volume of production and supply will be by far over and above the volume of demand for transport fuel ethanol requirement. The strategic plan for bio-ethanol development stated that the current proportion of the blend (10% ethanol and 90% gasoline) will gradually increase up to 25% ethanol and 75% gasoline up to 2015. In addition, the strategy indicated that the excess supply of bio-ethanol would be used for household energy consumption in replacement of kerosene (Ibid).

However, given the current status of the composition of gasoline vehicles that consume this blend; technically the proportion of ethanol to gasoline cannot go beyond 10% (Manaye, July 13, 2011 personal interview). In most cases countries use less percentage of blended gasoline for transport fuel such as 5% and 10%. This is due to the fact that less percentage blend doesn't require engine modification (WWI, 2006). In addition, IEA (International Energy Agency) restricted that beyond 10% bio-ethanol content on gasoline cannot be used in all models of gasoline vehicles across the board (IEA, 2009). On the other hand, although starting from the fiscal year just passed (2010/2011) the production of bio-ethanol is in excess of the demand and the efforts to use bio-ethanol for households' energy consumption is not likely to materialize in the near future.

Unless there are other alternative ways of use to optimize bio ethanol consumption, it will be a challenge for the sugar industry in particular and of the economy of the country in general. This project aims to assess the current status and future potential of bio-ethanol production; identify the composition of gasoline vehicles and what measures require from the government to increase bio-ethanol usage for transport fuel above 10% and recommend other alternative uses apart from transport.

## **2.2. Objectives of the Project**

The general objective of this project is to encourage the development of bio ethanol in Ethiopia and increase its alternative usage to improve the energy security of the country.



Under the above broad objective, the specific research objectives of this project include:

- a. To identify and analyze the status of the supply chain and the potential of fuel ethanol production from the Ethiopian Sugar Industry; examine the amount of bio-ethanol required for blending with gasoline for use as transport fuel and determine the excess supply and propose other ways of use for the country's energy requirement.
- b. To analyze the current composition of gasoline vehicles and propose measures on policy changes that will support the increased use of bio ethanol blend with gasoline for transport fuel.
- c. To examine and identify the potential contribution in terms of foreign exchange savings to the country.

### **2.3. Research Questions**

In order to fulfill the aforementioned objectives, there are questions this project work poses. These include:

- a. What is the current status and future potential of bio-ethanol production from molasses in the Ethiopian Sugar Industry? How much is the requirement for bio-ethanol to be blended with gasoline for transport fuel?

- b. How the composition of gasoline vehicles is and what policy measures are required that can help to increase the blend of ethanol with gasoline above 10%?
- c. What are other possible uses of the bio-ethanol apart from transport fuel?

## **2.4. Research Methodology**

The project work was conducted using a combination of descriptive and quantitative methods. The research utilized descriptive techniques in analyzing the issues and research questions that have been raised. The data collection methodology employed included both primary and secondary data sources.

### **Primary data**

Primary data was collected through interviews, as well as observations and discussion with informant groups.

### **Sampling Technique**

The sampling technique that was used to gather the data will be purposive sampling technique. It is particularly useful in identifying and contacting key stakeholders in the various organizations that directly or indirectly involve in the production and consumption of bio ethanol.

## **Interviews**

Primary data was collected through formal interviews of various actors and experts (50 selected people list attached in appendix I) who involve directly or indirectly in bio-ethanol production and use. The interviewees were mainly selected by contacting first the national bio-fuel forum coordinator, Ministry of Mines and Energy and then from respondents. In order to get an opportunity to supplement questions, if necessary, and allow the author to adjust questions, semi-structured open ended interview was conducted. This method allowed having a good interpersonal interaction, supplementary questions to be added in instances where the author needed more information. Moreover, it allowed clarifying confusing questions.

The interview with the various stakeholders allowed the author to obtain their viewpoints on the study topics. At times different views were presented on the topic and thus the same questions were discussed with various informants applying triangulation to reveal facts. Before each interview, the author designed a goal and in most of the interviews asked the informant to describe their role and the interaction with other actors in the development of bio-ethanol. The following are the key informants with whom the interview has been conducted. The names of the 50 people, organizations they work for and the date interviewed are shown in the bibliography section.

a) Ministry of Water and Energy (MWE)

- b) Ethiopian National Biofuel Coordination Office (NBCO)
- c) Ministry of Agriculture and Rural Development (MOARD)
- d) Ethiopian Sugar Corporation (ESC)
- e) Metehara Sugar Factory
- f) Fincha Sugar Factory
- g) MonjiShewa Sugar Factory
- h) Tendaho Sugar Factory
- i) Ethiopian Environmental Protection Authority (EPA)
- j) Ethiopian Quality and Standard Authority (EQSA)
- k) Forum for Environment
- l) Ethiopian Investment Authority (EIA)
- m) Ethiopian Agricultural Research Organization (EARO)
- n) Ethiopian Petroleum Enterprise (EPE)
- o) Ethiopian Transport and Communication Authority (ETCA)
- p) Nile Petroleum
- q) Yetebaberut petroleum
- r) National Oil Company (NOC)

## **Observations**

Data was also collected using direct observation. In order to get the real picture of sugarcaneplantation and sugar and bio-ethanol production, site visit was paid by the author and stayedtwo days at the Metehara Sugar Factory. The site visit was important to observe the farm as wellas the industrial activities. The cutting of sugar cane, sugarcane transport to the

sugar factory, sugar extraction and bio-ethanol production were observed by the author.

Informal discussion was also held with different individuals. This was intended to get the viewpoints of individual as well as to collect more information. Discussion with Metehara Sugarfactory was held to know more about the effluent treatment practice. Informal discussion was also held with departments of Ministry of agriculture and rural development to clarify the status of policies and their implications to bio-ethanol production.

### **Secondary Data**

Secondary data was also collected by consulting and reviewing different official documentations of government organizations that will directly and indirectly be influenced by the research project. In this regard, strategic plans, production and consumption data, import forecasts, project documents, and literature review on world production trend of bio-ethanol was collected and used for analysis.

### **Data Analysis and Interpretation**

The data collected was summarized and analyzed using tables and graphs. Based on the analysis interpretation of the results was described which became the basis for conclusions and recommendations. The findings were summarized in descriptive method.

## 2.5. Scope and Limitations

This project work covers a wide perspective on bio-ethanol that goes across several sectors and includes many actors involved in the system. The author believes such coverage provides greater understanding of the bio-ethanol development status and the connection with the relevant sectors and actors.

The geographical scope of the study is bound to bio-ethanol production and use in Ethiopia. Key stakeholders involved in the supply chain in the production and use of bio-ethanol are the main focus. As the goal of the project work is to help the country to develop a sustainable bioethanol market, the scope is narrowed down to identification, development analysis of bio-ethanol production and encourages its alternative uses.

The temporal scope foresees on short to medium term (next 5-10 years) and thus many of the analysis are relevant for these periods. Because bio-ethanol can be produced from a number of feedstocks and with the change in feedstock the whole supply chain will change. It may be possible other technologies could be developed in Ethiopia that can use second generation feedstocks. Also, the current direction of producing bio-ethanol using only molasses may change. There are intentions by private developers to use **sugarcane** and food crops. In that case, the existing set-up will take another form. In some cases however, some

suggestion and indications for long time perspective are mentioned to some extent.

This project is not without limitation that the author would like to acknowledge. The first limitation is the wide scope of the study. Analyzing the whole value chain of bio-ethanol development and analyzing its efficient alternative use. It needs multidisciplinary approach that requires inputs from different disciplines. As a result, the study may have limitations to encompass some important issues at depth and to satisfy experts in the specific discipline.

Another limitation is the information contained in the study may not be as detailed and exhaustive as it should be. Due to lack of prior study on the area, the data collection, and analysis was challenging. Absence of knowledgeable experts in the bio-ethanol energy was also one of the causes for lacking detailed information. Data on various aspects was incomplete and information needed for analysis was missing and thus the analysis made on the basis of such insufficient and incomplete data would be less vivid, unsatisfactory and shallow. Background information in the various sectors on the Ethiopian context was extremely poor, difficult to trace the original source and not updated.

## **2.6. Structure of the Project Work**

The structure of this project work begins with an introduction where among other things the research problem, the objective, the research questions, the methodology and the framework for analysis are

addressed. Then chapter 2 deals with the theoretical background. It serves the main basis for discussion of the key prospects and challenges associated with the Ethiopian bio-ethanol development. In order to facilitate the identification, analysis and discussion in the process of the research, this second chapter provides background information consisting of two sections.

The first section indicates general description about bio-ethanol that includes why it has been chosen to be used for transport fuel, what feedstocks are available for it, how it can be produced from these different feedstocks, what looks the yield from the different feedstocks, what seems the trend of production and demand for bio-ethanol at global level, what are the barriers and sustainability issues at global level as well as policies enacted by different countries to promote bio-ethanol. This section is believed to give background information to the project work describing what are known in the field. It shares the known facts of other studies that are closely related to this study. Moreover, local production and use of bio-ethanol is strongly linked with what is happening at the global level and indicating the trend in the global level would give what direction and requirement should the local development take and fulfill respectively.

The second section of the background chapter will describe about three sectors in Ethiopia on the basis of the first section. They are main sectors that would have influence or be influenced by the bio-ethanol program that include: agriculture, energy and transport. There are of course other



sectors that could be influenced as sectors are interlinked. But these three sectors are directly linked to the bio-ethanol development and are important examining them in the country in order to determine to what extent the bio-ethanol development would affect (positively or negatively) the present configuration.

For the analysis of the Ethiopian bio-ethanol setting, which is presented in chapter 3, the two sections of the background information are jointly used as input. For the analysis, an innovation system approach framework for technology development and diffusion is utilized. The framework is used to identify the structural component (actors, networks and institutions) of the bio-ethanol development in Ethiopia and to assess the current status and future potential of actors.

Following the analysis, key findings and main recommendations are discussed in Chapter 4. They are derived from the analysis. The identification of prospects and challenges are done in two steps. First the theoretical explanations are formulated in the background part. Then they are checked through interview and observation. The discussion is followed by key findings and recommendations for overcoming the challenges and redevelops sustainable alternative uses in the domestic market.

## **2.7. Relevance of the Project Work**

The research contributes to developing knowledge on the bio-ethanol market in Ethiopia thereby providing an important value to policy makers,

academic researchers, business society, industry actors and interested groups.

*For policy makers:* it provides a clue on policy options that could be considered to adopt in Ethiopia context to support the bio-ethanol development. The challenges and the means to overcome them and the social and environmental concerns highlighted in the study could also provide important inputs for policy makers to make interventions for sustainable domestic bio-ethanol market.

*For business society:* Bio-ethanol development in the country is at an early stage. The information contained in the study provides important understanding about bio-ethanol in general and the status in Ethiopia in particular. Knowing the status in Ethiopia could be important to businesses to have a basic data and the opportunities thereon. In addition, the policy options presented will equip them with essential background information to open dialogue with the government to introduce stimulating condition.

*For academic researchers:* The study can also serve as a platform to provide basic information on the bio-ethanol development to make further research on areas of data insufficiency. The indication of areas lacking sufficient data and potential areas for further study would guide researchers to select priority areas and undertake further study.

*For industry actors:* The implication of bio-ethanol is not well understood in Ethiopia. This study tries to indicate implications associated with bio-

ethanol expanded production. Knowing these issues would enable industry actors to consider them in their action and when they setup new facilities thereby available data could be captured, analyzed and improvement achieved.

## **CHAPTER TWO**

### **3. BACKGROUND ON BIO-ETHANOL AND ETHIOPIA**

This theoretical part consists of two parts. The first part indicates general description about bio-ethanol. The second section will give information about Ethiopian main sectors that could potentially be influenced by the bio-ethanol program. The information displays the current situation of the sectors focusing on points related to the bio-ethanol development.

#### **3.1. Bio-Ethanol Main Issues**

Biofuels have attracted global attention due to concerns on climate change, energy security and dependency and import burden of petroleum products. They are increasingly considered by many countries as much as feasible to substitute the fossil fuel source in the transport sector.

Currently bio-ethanol and biodiesel, sometimes referred to as first generation biofuels, are the most important ones as both can be used blended or in neat form although neat usage requires engine modification (IAE, 2004). Biodiesel is blended with petroleum-based diesel whereas bio-ethanol is blended with gasoline. Biodiesel is derived from oil crops like rapeseed, palm-oil, jatropha, sunflower, and soy while bio-ethanol is based on starch crops like sugarcane, sugar-beets, corn, wheat and sorghum (Dufey, 2006). Since the focus of the study is on bio-ethanol the following section presents background information exclusively on bio-ethanol.

### **3.2. Bio Ethanol Background**

There is semantic confusion with regard to the term bio-ethanol. Very often the term is used as a synonym for alcoholic beverages. This is misleading, even though ethanol may be used as a raw material for the production of spirits. Bio-ethanol is a clear, colorless, flammable oxygenated hydrocarbon, with the chemical formula  $C_2H_5OH$  (Berg, 2004). Even though the definition is fairly straightforward, there are various categories for describing a particular type of ethyl alcohol which are not mutually exclusive:

- by feedstock
- by composition
- by end use

The feedstock and therefore the processes by which bio-ethanol can be produced are diverse. Synthetic alcohol may be derived from crude oil or gas and coal. Agricultural alcohol may be distilled from grains, molasses, fruit, sugar cane juice, cellulose and numerous other sources. Products, fermentation and synthetic alcohol are chemically identical (Breg, 2004).

Synthetic alcohol is concentrated in the hands of a couple of mostly multi-national companies such as Sasol with operations in South Africa and Germany, SADAF of Saudi Arabia, a 50:50 joint venture between Shell of the UK and Netherlands and the Saudi Arabian Basic Industries Corporation, and BP of the UK as well as Equistar in the US (Berg, 2004).

Another distinction which is of importance in the field of ethanol is the one between anhydrous and hydrous alcohol. Anhydrous alcohol is free of water and at least 99% pure. This ethanol may be used in fuel blends. Hydrous alcohol on the other hand contains some water and usually has a purity of 96%. In Brazil, this ethanol is being used as a 100% gasoline substitute in cars with dedicated engines. The distinction between anhydrous and hydrous alcohol is of relevance not only in the fuel sector but may be regarded as the basic quality distinction in the bio-ethanol market share (Berg, 2004).

The final distinction which is necessary in order to understand the dynamics of the world ethanol market is by end-use. Certainly the oldest form of use of alcohol is that of a beverage. The most important market for bio-ethanol as an industrial application is solvents. Solvents are primarily utilized in the production of paints and coatings, pharmaceuticals, adhesives inks and other products. Bio-ethanol represents one of the most important oxygenated solvents in this category. Production and consumption is concentrated in the industrialized countries in Northern America, Europe and Asia. It is the only market where synthetic ethanol producers hold a significant market share (Berg, 2004).

The last usage category is fuel alcohol. As mentioned before, fuel alcohol is either used in blends, for example in gasohol or diesohol, or in its pure form. However, at present Brazil is the only country that uses ethanol as a 100% substitute for gasoline (IEA, 2010).

### 3.3. Why Bio-ethanol use for Transport

Bio-ethanol is a liquid obtained by distillation of fermented sugar. It has become preferential because of its potential of matching the convenient features of petroleum at competitive price (Wyman, 1996). It can also be produced from various resources available domestically: agriculture and forestry residue, organic portion of municipal solid waste, woody and herbaceous crops and dedicated starchy crops (Rutz D. and Jansse R., 2008). It offers a number of benefits that includes: high **octane** and high heat of vaporization that allow it to achieve higher engine efficiency. Its use reduces ozone and smog formation compared with the conventional gasoline due to its low volatility and photochemical reactivity (Dufey, 2006).

Its blended use reduces fossil fuel consumption and provides oxygen to promote more complete combustion that results in less exhaust emission of carbon monoxide and unburned hydrocarbon (Wyman, 1996). In addition to using the existing petroleum infrastructure, bioethanol can be blended with gasoline in any proportion up to 10 per cent without the need for engine modification (IAE, 2004). Blends of 5 percent or 10 percent of bio-ethanol in gasoline are denominated as B5 and B10, respectively (Dufey, 2006). In some cases they are denominated as E5 for 5% bio-ethanol blend (5% Bio-ethanol and 95% gasoline) and E10 for 10% (10% bio-ethanol and 90% gasoline) (Dufey, 2006).

Bio-ethanol greatest benefit lies in its potential to reduce greenhouse gas emissions by partial replacement of oil as a transport fuel (IAE, 2004). This could help developed countries meet their commitments under the Kyoto Protocol and mitigate the effects of climate change. In economic terms, today's high gasoline price makes bio-ethanol from the most efficient producer countries competitive (Dufey, 2007). These are largely developing nations. It also reduces the burden of foreign currency expenditure for poor countries that are net importer of petroleum products and have potential to produce and use bio-ethanol (WWI, 2006).

Other considerations behind bio-ethanol market development include the promotion of greater energy security, rural development, and poverty reduction (Dufey, 2007).

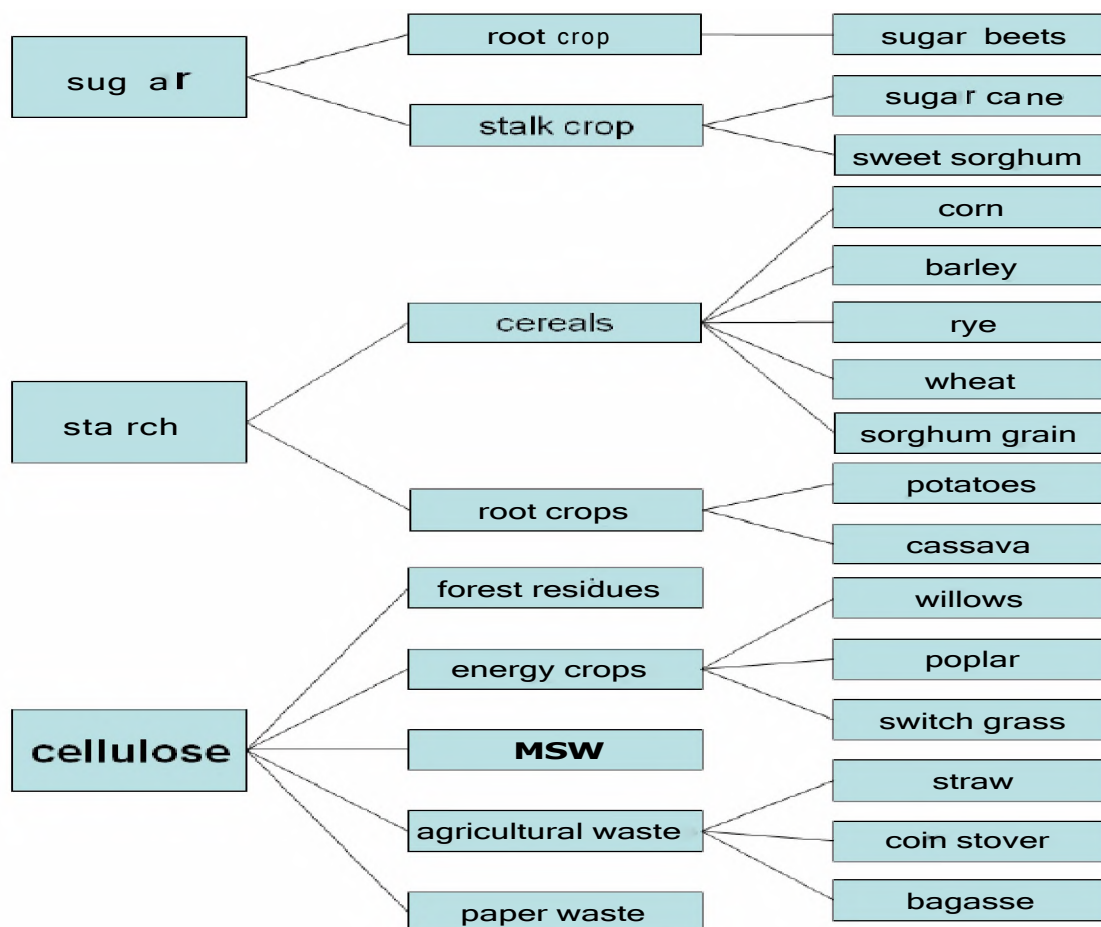
### **3.4. Feed Stock Production**

Different feedstock are available for producing bio-ethanol as it can be derived from any biological raw-materials that contain sugar or materials that can be converted into sugar from starch or cellulose (Dufey, 2006). For instance, sugarcane and beets are feedstock types that contain sugar whereas corn, wheat, and other cereals contain starch (Rutz D. and Jansse R. 2008).

On the next page figure 2-1 shows the different feed stocks that can be used to produce bio-ethanol.



Figure 2-1 Types of feedstocks for bio-ethanol production



Source: Rutz D. and Jansse, R. 2008

Bio-ethanol from sugar and starch bearing plants is readily available and the feedstocks of such plants are called first generation. They are characterized by only parts of the plants (sugar or starch) are used for bio-ethanol production (WWI, 2006). On the other hand, next generation feedstocks types are used wholly for bio-ethanol production (stalks, grains, tubes) (Ibid).

These different feedstocks demand various processing steps to deliver bio-ethanol depending on their embedded sugar type. This is depicted in table 2-1 on the next page.

Generally, the feedstock's are converted to bio-ethanol by acid or enzyme based approach. In both cases, the feedstock first treated in order to facilitate the next steps. These may be size reduction, separation and cleaning as has been shown under harvesting technique in table 2-1. The next step is feedstock conversion to sugar where acids and enzymes are used to break apart to form their component sugar (WWI, 2006). Then the sugars are fermented to bioethanol by adding yeasts, bacteria or other suitable organisms and then the bio-ethanol is separated by distillation.

The next generation feedstocks comprise cellulose rich organic materials that include biomass such as wood, tall grasses and crop residues (IEA, 2004), which are harvested for their total biomass. These feedstocks can be converted into bio-ethanol by advanced technical processes. The organic parts of the municipal solid waste (MSW) are also one of the feedstocks under the next generation.

**Table 2-1: Bio-ethanol production steps by feedstocks and conversion technique**

Feedstock type	Feedstock	Harvest technique	Feedstock conversion to sugar	Process heat	Sugar conversion to Alcohol	Co-products
Sugar crops	cane	Cane stalk cut, mostly taken from field	Sugars extracted through bagasse crushing, soaking, chemical treatment	Primarily from crushed cane (bagasse)	Fermentation and distillation of alcohol	Heat, electricity, molasses
	sugar beet	Beets harvested, foliage left on the field	Sugar extraction	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed, fertilizer
Starch crops	wheat	Starchy parts of plants harvested; stalks mostly left in the field	Starch separation, milling. conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g. distillers dried grains)
	com	Starchy parts of plants harvested; stalks mostly left in the field	Starch separation, milling. conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g. distillers dried grains), sweetener
	potatoes	Potatoes harvested, foliage left on the field	Washing, mashing, cooking, starch separation, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed, industrial use
Cellulosic crops	trees	Full plant harvested (above ground)	Cellulose conversion to sugar via saccharification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.
	grasses	Grasses cut with re growth	Cellulose conversion to sugar via saccharification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.
Waste biomass	Crop residues, forestry waste, municipal waste, mill waste	Collected, separated, cleaned to extract material high m cellulose	Cellulose conversion to sugar via saccharification (enzymatic hydrolysis)	Lignin and excess cellulose	Fermentation and distillation of alcohol	Heat, electricity, animal feed, bioplastics, etc.

Source: Rutz D. and Jansse,R. 2008

The yields of the feedstocks also varies. For instance the yields of the first generation feedstocks are shown in Fig.2-2. It shows that bio-ethanol production from sugarcane is the highest per hectare.

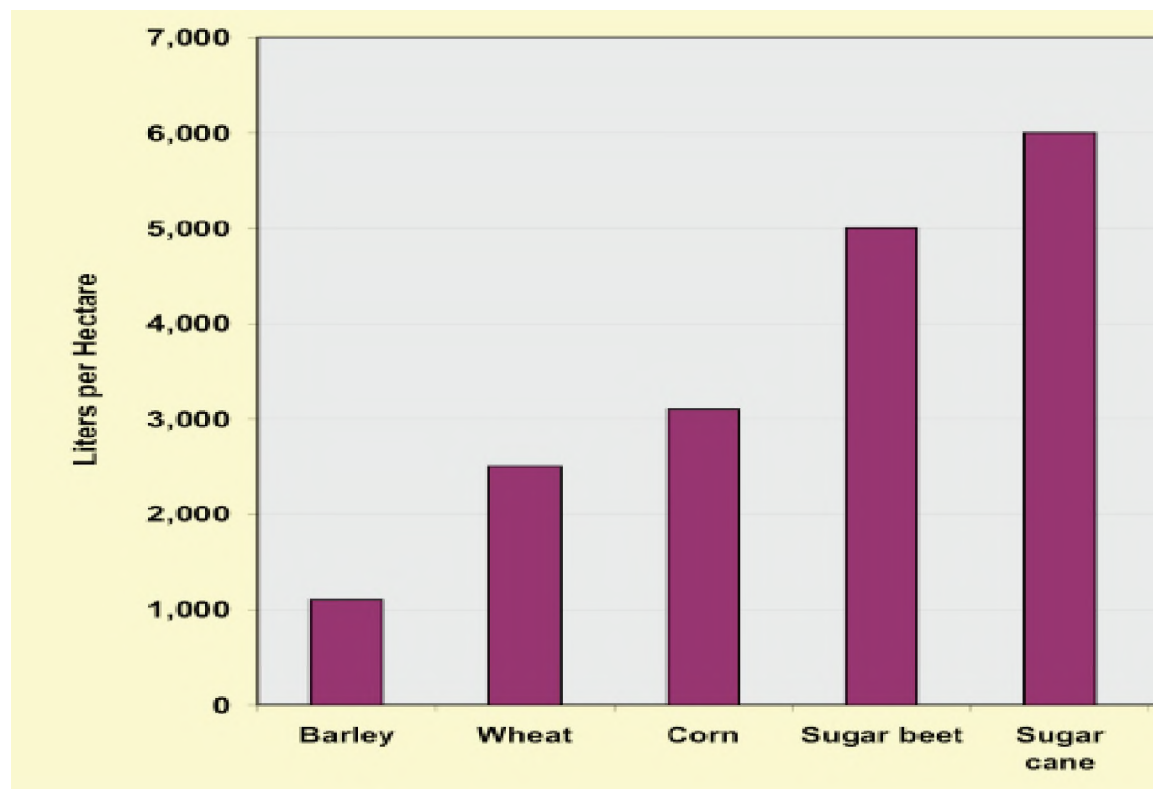


Figure 2-2 Bio-ethanol yield from first generation feedstock

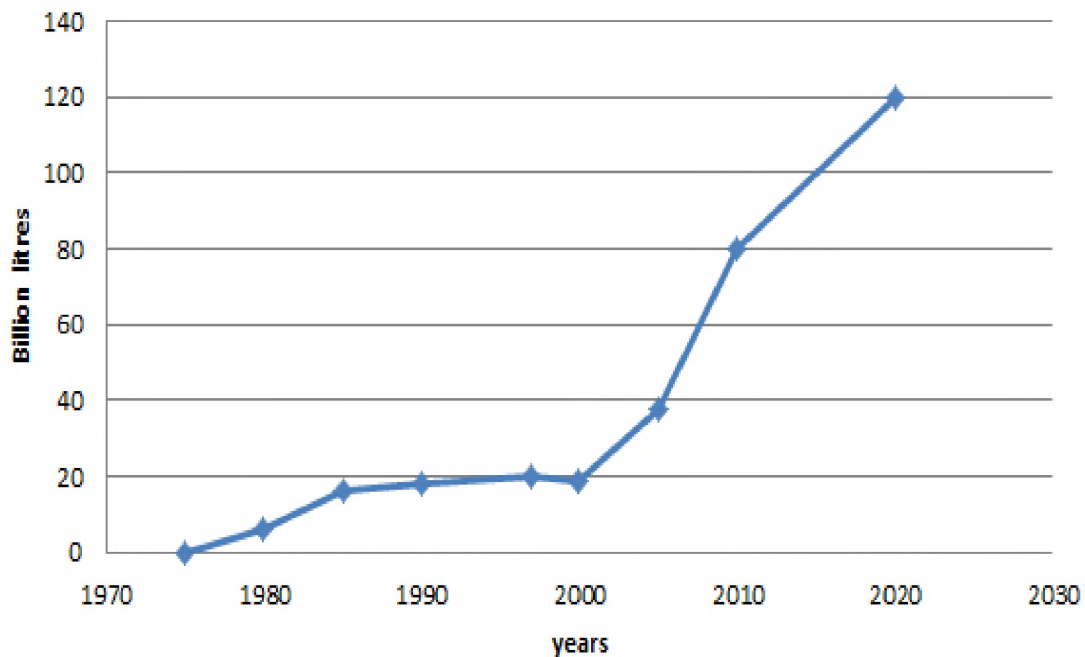
Source: World Watch Institute, 2006

### 3.5. Current Status and future trends of bio-ethanol

The production and use of bio-ethanol is rising worldwide as a result of various driving factors as described in fig. 2.3 below. The production in 2000 was around 20 billion liters and the quantity doubled to around 40 billion liters in 2005 (WWI, 2006). Predictions indicate that the production

would reach 120 billion liters by the year 2020 (Bio-Fuel Market, 2007 and Dufey, 2006).

### Global Bio-ethanol production trend



*Fig. 2.3. Current Status and future trend of bioethanol production*

*Source: Adapted from World watch Institute, 2006 and Bio-fuel market, 2007*

The future supply of bio-ethanol is expected to exceed the demand which implies that there will be opportunities for low-cost producer developing countries, especially for tropical countries with low labor and land costs (Dufey, 2007).

### **3.6. Bio-ethanol as a Transport Fuel**

Bio-ethanol and bio-ethanol/gasoline blends have a long history as alternative transportation fuels. It has been used in Germany and France as early as 1894 by the then incipient industry of internal combustion (IC) engines. Brazil has utilized bio-ethanol as a transportation fuel since 1925. The use of bio-ethanol for fuel was widespread in Europe and the United States until the early 1900s. Because it became more expensive to produce than petroleum-based fuel, especially after World War II, bio-ethanol's potential was largely ignored until the oil crisis of the 1970s.

Since the 1980s, there has been an increased interest in the use of bio-ethanol as an alternative transportation fuel. Countries including Brazil and the United States have long promoted domestic bio-ethanol production. In addition to the energy rationale, bio-ethanol/gasoline blends in the United States were promoted as an environmentally driven practice, initially as an octane enhancer to replace lead. Bio-ethanol also has value as an oxygenate in clean-burning gasoline to reduce vehicle exhaust emissions (Dufey, 2006)

Bio-ethanol has a higher octane number (108), broader flammability limits, higher flame speeds and higher heats of vaporization. These properties allow for a higher compression ratio and shorter burn time, which lead to theoretical efficiency advantages over gasoline in an IC engine. Octane number is a measure of the gasoline quality for prevention of early ignition, which leads to cylinder knocking.

The fuels with higher octane numbers are preferred in spark-ignition internal combustion engines. An oxygenate fuel such as bio-ethanol is provided a reasonable antiknock value (IAE, 2004).

Disadvantages of bio-ethanol include its lower energy density than gasoline (bio-ethanol has 66% of the energy that gasoline has), its corrosiveness, low flame luminosity, lower vapor pressure (making cold starts difficult), miscibility with water, toxicity to ecosystems, increase in exhaust emissions of acetaldehyde, and increase in vapor pressure (and evaporative emissions) when blending with gasoline.

Bio-ethanol can be used in various methods as a transportation fuel. It can be directly used as a transportation fuel or it can be blended with gasoline. Bio-ethanol can be mixed with gasoline it is substituting for and can be burned in traditional combustion engines with virtually no modifications needed. Bio-ethanol is most commonly blended with gasoline in concentrations of 10% bio-ethanol to 90% gasoline, known as E10 and nicknamed "gasohol". In Brazil, bio-ethanol fuel is used pure or blended with gasoline in a mixture called gasohol (24% bio-ethanol and 76% gasoline) (IAE, 2004).

Bio-ethanol can be used as a 5% blend with petrol under the EU quality standard EN 228. This blend requires no engine modification and is covered by vehicle warranties. With engine modification, bio-ethanol can be used at higher levels, for example, E85 (85% bio-ethanol). Bio-ethanol is an oxygenated fuel that contains 35% oxygen, which reduces

particulate and nitrogen oxides (NO<sub>x</sub>) emissions from combustion. Using bio-ethanol blended fuel for automobiles can significantly reduce petroleum use and exhaust greenhouse gas emission. Adding bio-ethanol to gasoline increases the oxygen content of the fuel, improving the combustion of gasoline and reducing the exhaust emissions normally attributed to imperfect combustion in motor vehicles, such as CO and unburned hydrocarbons.

### **3.7. Background on Ethiopia- Main Sectors**

The main sectors that have influence or be influenced by the bio-ethanol program will be agriculture, energy and transport. There are of course other sectors that could be influenced as sectors are interlinked. But these three sectors are directly linked to the program and worth examining them in order to determine to what extent the bio-ethanol development in the country can affect (positively or negatively) the present configuration. Besides, looking into the sectors gives background information for the analysis in part five. Thus the following part describes briefly the current situation of these sectors.

### **3.8. The Agricultural Sector**

Ethiopia is an agrarian economy based country. Its total area is 1,127,127 square kilometers, of which 7444 square kilometers is covered by water. About 66% of the total land area is considered to be potentially suitable for agriculture, whereas only 15% of this land area is cultivated (ONAR 1, 2002). In terms of the area that can be developed by surface



waterirrigation, it is estimated at about 3-4 million hectares, of which not more than 5% or 200,000hectares of land developed. Only about 10-15% of the total land is presently covered by forestas a result of rapid deforestation during the last 30 years (Country profile, 2005). The maincauses for this rapid deforestation are extensive farming activities, overgrazing anduncontrolled exploitation for fuel wood (ONAR 1, 2002). Of the remainder, the majority partof the land is utilized by pastoralists. Some land is dry and infertile for agriculture or any otheruse (ONAR 1, 2002).

Agriculture in Ethiopia is the main sector in the economy, accounting for an average of 45%of the GDP, about 85% of employment generation, and 85 % of export earnings. Crops arethe major contributors of the GDP with in the agriculture sector and account about 64%,followed by livestock accounting 23% and forestry with 13% (Agricultural and Rural

Development, 2002). Within the agricultural farming, the commercial farming is limited,whereas the mixed farming of the smallholder agriculture and the pastoral livestock system arethe leading one. The smallholder agriculture accounts for over 95% of the cultivated land andproduction (Birehanu, 2011). Production system is largely characterized by subsistencefarming, low levels of external inputs, dependency in rainfall and limited integration into the market (Birehanu, 2011). The highlands (above 1500m above sea level) which amount to beabout 44% of the highland mass are the greatest economic asset of the country. They shelterabout 88 % of the total population and account

for over 90% of the economic activity, including about 95% of the cultivated lands and 67% of the livestock population. About 60% of the highlands exhibits slopes in excess of 30% (MOARD, 2002).

### **3.9. Land ownership**

The existing constitution of the Federal Democratic Republic of Ethiopia with regard to land ownership states that the right to ownership of land is exclusively vested in the State and in the People of Ethiopia. In order to implement this provision, further a rural land administration law is enacted having the following salient features as Ethiopia is divided into regional administrative states (Agricultural and Rural development Department, 2002):

- Land is a common property of the Nations, Nationalities and Peoples of Ethiopia and it shall not be subject to sale or to other means of exchange.
- Regions shall administer rural land in accordance with the general provision of this proclamation and each Regional Council shall enact a law on land administration of its region. Experts rather recommend the ownership to be decided based on the socio-economic situation of the country, preferably substantiated by research (EEA, 2002). However, to close any policy dialogue on the issue, the government inserted the key feature of the existing land tenure system (public ownership of land) as one of the articles of the constitution (EEA, 2002). In connection to land tenure, a study

made by the Ethiopian Economic Policy Research Institute indicates that the national average holding is 1.02 ha per household where 37.6% of the households have less than 0.5 hectare per household and 63% of the households own less than or equal to 1 hectare per household. The average landholding per active farm labor force (land-labor ratio) is only 0.38 hectare and about 11% of the households are landless (EEA, 2002). The land-holding size significantly determines the level of farm income; and the low level of income of farm households in Ethiopia is largely a result of both the small size of holding and the low level of productivity (EEA, 2002).

### **3.10. Crop production**

About 744 000 square kilometer of the land area (66% of the total land) is considered to be potentially suitable for agricultural production while only close to 15% (112 000 square kilometers) is actually cultivated; almost all are dependent on rainfall. Farming in Ethiopia is mostly in the hands of peasants, who cultivate individual small size plots-all land belongs to the state. Given the suitability of the climate, Ethiopia cultivates a variety of crops. In the highlands, grains (barley, corn, teff, and wheat) as well as pulses and oilseeds are the major crops; whereas at lower elevations, sorghum and sugarcane are favored. According to the 2007 Ethiopian Statistics Authority report, of the private holding cultivated area, which accounts 95 % of the total cultivated land, cereals

occupied 8 471 920 ha, oilseeds occupied 741 791 ha, pulses occupied 1 379 046 and Sugarcane occupied 42 995 ha (CSA,2008). The types of crops, the area covered and the yield per ha of these private holdings are shown in table 2-2 below.

*Table 2-2 Area under cultivation, production and yield of major crops for 2005/06 main crop season of Ethiopia*

<b>S/N</b>	<b>Crop Type</b>	<b>Cultivated Land (ha)</b>	<b>Production (ton)</b>	<b>Yield (ton/ha)</b>
<b>1</b>	<b>Cereals</b>	<b>8 471 920</b>		
<b>1.1</b>	<b>Barely</b>	<b>1019314</b>	<b>1352140</b>	<b>1.33</b>
<b>1.2</b>	<b>Maize</b>	<b>1694522</b>	<b>3776440</b>	<b>2.23</b>
<b>1.3</b>	<b>Sorghum</b>	<b>1464318</b>	<b>2316041</b>	<b>1.58</b>
<b>1.4</b>	<b>Finger millet</b>	<b>374072</b>	<b>484409</b>	<b>1.30</b>
<b>1.5</b>	<b>Teff</b>	<b>2404674</b>	<b>2437749</b>	<b>1.01</b>
<b>1.6</b>	<b>Wheat</b>	<b>1473917</b>	<b>2463064</b>	<b>1.67</b>
<b>1.7</b>	<b>Oats</b>	<b>32798</b>	<b>36243</b>	<b>1.10</b>
<b>2</b>	<b>Oil Seeds</b>	<b>741791</b>		
<b>2.1</b>	<b>Linseed (Flax)</b>	<b>174108</b>	<b>108224</b>	<b>0.62</b>
<b>2.2</b>	<b>Neug (sunflower)</b>	<b>274720</b>	<b>147759</b>	<b>0.54</b>
<b>2.3</b>	<b>Sesame</b>	<b>211312</b>	<b>149387</b>	<b>0.71</b>
<b>2.4</b>	<b>Ground nuts</b>	<b>37126</b>	<b>51080</b>	<b>1.38</b>
<b>2.5</b>	<b>Sunflower</b>	<b>13019</b>	<b>11176</b>	<b>0.86</b>
<b>2.6</b>	<b>Rapeseed</b>	<b>30637</b>	<b>29206</b>	<b>0.95</b>
<b>3</b>	<b>Pulses</b>	<b>1379046</b>		
<b>3.1</b>	<b>Chick-peas</b>	<b>200066</b>	<b>253871</b>	<b>1.27</b>

<b>3.2</b>	<b>Field peas</b>	<b>221715</b>	<b>210095</b>	<b>0.95</b>
<b>3.3</b>	<b>Haricot beans</b>	<b>223357</b>	<b>222701</b>	<b>1.00</b>
<b>3.4</b>	<b>Faba beans</b>	<b>459202</b>	<b>576156</b>	<b>1.26</b>
<b>3.5</b>	<b>Lentils</b>	<b>97110</b>	<b>81049</b>	<b>0.84</b>
<b>3.6</b>	<b>Grass pea</b>	<b>124954</b>	<b>183784</b>	<b>1.47</b>
<b>3.7</b>	<b>Soya Beans</b>	<b>6352</b>	<b>5849</b>	<b>0.92</b>
<b>3.8</b>	<b>Fenuqreek</b>	<b>20762</b>	<b>16398</b>	<b>0.79</b>
<b>3.9</b>	<b>Gibto</b>	<b>25526</b>	<b>28717</b>	<b>1.13</b>
<b>4</b>	<b>Other crop</b>			
<b>4.1</b>	<b>Sugarcane</b>	<b>42995</b>	<b>1374712</b>	<b>31.97</b>

*Source: Central Statistics Authority of Ethiopia*

### **3.11. Energy sector**

Ethiopia's Energy consumption is predominantly based on biomass energy sources. The lionproportion (95.1%) of the country's energy demand is met by traditional energy sources suchas fuel wood, charcoal, branches, dung cakes and agricultural residues (Energy Policy, 1994).The balance is met by commercial energy sources such as electricity and petroleum.Petroleum accounts 4.3% and electricity 0.6% (EMSA, 2001). The most important issue inthe energy sector is the supply of household fuels, which is associated with massivedeforestation and the resultant land degradation (EEA, 2004). The increasing scarcity of fuelwood is compounded by Ethiopia's high population growth rate.The energy sector in Ethiopia remains heavily dependent on biomass despite the country'shuge potential of various energy production resources.

However, the exploitation rate is very small, except for biomass. Table 2-3 below indicates the resource potential and the exploited status of the various energy sources.

Even though per capita energy consumption of Ethiopia is among the lowest in the world, which is 28KW, the gap between sustainable biomass supplies and demand is constantly widening. The demand of households for forest products in many areas exceeds by far the annual incremental yield from the existing forest. As a result, the price of fuel wood has soared to a record high that people living in cities are forced to switch to fossil fuel use. The current price for one metric ton of fuel wood reaches as high as Birr 200.

**Table 2-3 Energy resource potential and exploited rate in Ethiopia**

Overview of energy status			
Resource	Unit	Potential	Exploited (%)
Hydropower	MW	>45000	<5
Solar/day	KWh/m <sup>2</sup>	4-6	0
Wind Speed	m/s	3.5-8	0
Geothermal	MW	1070	0
Wood	Millions tons	1120	50
Agricultural waste	Million tons	15-20	30
Natural gas	Billion m <sup>3</sup>	113	0
Coal	Million tons	96.3	0

Source: Meskir, 2007

The major use of energy, about 89% of the overall energy consumption in the country, is the households. The second most important sector in terms of energy consumption is industry (4.5%) followed by services and others (3.6%) while agriculture and transport were attributed to the remaining 2.3% (EEPCO, 2005). The consumption of energy is directly related to the availability of energy source, the size of the population and the price (Meskir, 2007).

Table 2.4 shows the sector-wise percentage usage distribution of energy source type in Ethiopia.

**Table 2-4 Sector wise energy source utilization percentage distribution**

Sector	Energy source		
	Biomass (%)	Petroleum (%)	Electricity (%)
Households	98.6	1.1	0.3
Industry	75.7	17.3	7
Services	94.7	1.3	4.4
Transport	—	100	—
Agriculture	-	100	-

**Source: Meskir, 2007**

Transport and agriculture sectors are entirely dependent on imported fossil fuel as Ethiopia doesn't have at the moment vehicles run by electricity and biofuel. Petroleum import quantity is shown in part 2.3.3.

With regard to electricity use, currently the country is able to generate 831 MW of electricity per hour from hydro dams, which accounts 98% of all electricity production, the rest comes from fossil fuel and only about 14% of the population has access to electricity (NBE, 2007 and EEPCO, 2005).

The current holdings of the power sector is entirely controlled by the state, no private power supplier exists in the country though provisions are given to private investors (see next part on energy policy). Generally the dependency of the hydro-power plants on rain, depletion of forests for biomass source and price escalation of petroleum products bear heavy burden to fulfill the country's energy requirement and it is mandatory to expand the energy mix from available resources, giving priority on the basis of social-economic and environmental benefits.

### **3.12. Transport sector**

The transport sector contributes only about 6% of the total GDP in Ethiopia albeit its crucial role in supporting agricultural development, facilitation of trade and domestic competitiveness (NMSA, 2001). Road transport, single railway, airline and ships are the conventional transport means. The dominant mode of transport in Ethiopia, however, is road transport, having share of 90% in transporting passenger and cargo across the country. The road density is among the lowest in Africa estimated to be about 30 km per 1000 square kilometer (NMSA, 2001). The development of surface transport service has been limited due to



widetopographical variations, extremely rugged terrain; sever climatic conditions, and a widelydispersed population (NMSA, 2001). These factors make construction of transportinfrastructure not only physically difficult but also extremely costly.

As mentioned, the road transport plays important role in the movement of goods andpassengers as compared to other modes of transport. According to the Ethiopian RoadAuthority of the Ministry of Transport and Communications, totally 354,107 vehicles foundregistered up to the year 2010 (RTA, 2011). These vehicles consume either gasoline or gas oil fuel type. Of this total number of vehicles, 178,618 are vehicles that consume petrol or gasoline.

The transport sector consumes more than 50% of the total petroleum products the country isimporting every year (MME, 2007). The volume of the fuel consumed by road transportvehicles has the greater share and currently become a challenge due to increasing quantity andprice escalation of the products. Stated below in table2-5 is the country's petroleumconsumption, excluding kerosene which is used for household cooking fuel, in quantity andvalue respectively for the last 6 years.

The share of gasoline of the total consumption declined from 9.3 % in 2005/06 to 7.7% in2009/10. This is due to the fact that vehicle importers have been inclined more to diesel drivenvehicles as a result of gasoline cost (Esayas, 2011). In terms ofquantity, gasoline showed 13.6 % increment from 2005/06 to 2009/10.

As a result of the increment and huge expenditure of money for petroleum products, the government regularly adjusts the local selling price of the products including the subsidies to transfer some of the increment happening in the world market to consumers.

**Table 2-5: Petroleum import data (in quantity)**

	Importation quantity in metric tons (MT)					
	Gasoline	Jet/kerosene	Diesel oil	LFO	HFO	Total
2005/06	137193	370401	811689	41521	117198	1478002
2006/07	143743	402311	905478	42255	116429	1610216
2007/08	139093	482173	1073148	49692	138059	1882165
2008/09	150099	506497	1203567	36421	116506	2013089
2009/10	155805	529857	1237922	10714	100967	2035265
2010/2011	167340	551148	1395377	48478	117940	2280283

Source: EPE, 2011

**Table 2-6: Petroleum Import Data in Value**

	Importation in value in USD					
	Gasoline	Jet/kerosene	Diesel oil	LFO	HFO	Total
2005/06	78146971	217222639	40330800	51399640	35273178	747947198
2006/07	84245805	246366769	519146279	14291536	8139482	902189871
2007/08	116129644	449776779	93803376	32545012	570654000	1600044312
2008/09	85926963	357984568	75096086	217939958	47844701	1260057054
2009/10	106316446	43931636	79409055	15732120	51626457	1301697210
2010/11	195150381	596562939	157029460	68050391	10737808	28893456007

Source: EPE, 2011

## **CHAPTER THREE**

### **4. ANALYSIS**

#### **4.1. Background Analysis**

This part analyses the situation currently prevailing in Ethiopia on production and use of bio-ethanol. The background information presented in part 2 is used to address important issues on the development of bio-ethanol. Using the background information as input and the framework as guidance, the status, potential and challenges in the production and consumption of bio-ethanol are identified.

##### **4.1.1. Main firms in the production level of bio-ethanol**

The production level of the value chain consists of feedstock production, sugar extraction and fermentation/distillation. This production stage of the value chain is dominated by the state-owned sugar factories that are engaged mainly in sugar cane plantation, sugar extraction and bio-ethanol distillation. Currently there are three sugar factories, Wonji-Shoa, Metehara and Fincha, which have been in operation at least for decades and the fourth, Tendaho, which will be the biggest in capacity is under the project phase (Shimeles and Aklilu, 2012, January 8, personal interview). All the factories cultivate sugarcane for extraction of sugar and they produce or intend to produce bio-ethanol from the by-product obtained from the sugar extraction. Their role and current status as well as their future intention are elaborated below.

#### **4.1.2. Feedstock production**

The three factories cultivate feedstock for the production of sugar. The feedstock used for production of sugar by the sugar factories is solely sugar cane. Sugar cane plant is generally grown between the latitudes of 30° North and South mainly because it requires a warm climate coupled with adequate natural or artificial water (Shimeles, 2011).

Due to this factor the farm areas of all the sugar factories are located in areas considered suitable for sugarcane cultivation in the country and the factories are also constructed close to these plantations. The following table shows general description of the sugar cane production area of these sugar factories.

From the interviews (Shimeles, Azemera and Afework, 2011) and observation from site visit the following information is obtained. Sugarcane cultivation in Ethiopia follows a system similar to that of the Brazilian. Before planting at the first time, the soil is intensively prepared and necessary fertilizers are applied. During plantation the plants are treated with artificial fertilizers including filter cake from the bio-ethanol plant. After 12-18 months, the cane is ready to be cut.

**Table 3-1: Description of Sugar Factories sugarcane plantation areas**

<b>S/N</b>	<b>Description</b>	<b>Name of the Sugar Factories</b>			
		<b>Wonji-Shia</b>	<b>Metehara</b>	<b>Fincha</b>	<b>Tendaho</b>
1	Distance from the capital	110km to the east	210km to the east	340km north-west	600km north-east
2	Annual Rainfall	800mm	550mm	1250mm	234mm
3	Average min. temperature	15.3 <sup>0</sup> c	17.53 <sup>0</sup> c	15 <sup>0</sup> c	21.8 <sup>0</sup> c
4	Average max. temperature	26.9.9 <sup>0</sup> c	32.6 <sup>0</sup> c	31 <sup>0</sup> c	39.7 <sup>0</sup> c
5	Altitude	1540 ma.s.l	950m a.s.l	1650m a.s.l	340m a.s.l
6	Source of water	Hydro dam on Awash river	Hydro dam on Awash river	Hydro dam on fincha river	Dam on a river
7	Irrigation system	Furrow irrigation	Furrow	Sprinkler	Irrigation

Source: Ethiopian Sugar Corporation (ESC)

For cutting and harvesting, it is a common practice to burn down the cane in order to simplify manual harvesting and avoid possible attack by insects and animals with in the farm. After cutting, the cane is loaded on trailers and transported to the sugar factories. The same plantation continues to deliver cane for 7-8 years and when the yield declines another cycle will start. The current status and future expansion scheme of the plantation the sugar factories are able to cultivate and

envisage to cultivate respectively are summarized in table 3-2 on the next page.

**Table 3-2 Current and future sugar cane plantation area and quantity**

S/N	Description	Name of the Sugar Factories			
		Wonji-Shoa	Metehara	Fincha	Tendaho
1	Current sugar cane area (ha)	7022	10100	9500	-
2	Current sugar cane production (tone cane per day)	3100	5000	4400	-
3	Expansion sugar cane area (ha)	15978	10000	10500	50000
4	Sugar cane production from the expansion area (tone cane per day)	9400	5000	8100	26000

Source: ESC, 2011

The table shows the current areas cultivated and the production quantity of sugarcane from these areas as well as the future expansion plan both from the existing sugar factories and the project being constructed. The cultivation is mainly done by the factories themselves on the land they are allocated. Insignificant quantity is planted by out-growers living in the surrounding in the case of Metehara. The factory gives seeds and

proper advice and later it buys the cane the out-growers cultivated. The price is based on the sugar content the cane would deliver during extraction. Otherwise, the practice of cultivation and harvesting are done entirely by the factories themselves by employing seasonal labourers. Since cultivation and harvesting jobs are seasonal, the factories do not employ permanent workers for the labour works of plantation cutting and loading to trailers and hence do not retain the workers in the entire year. Cultivation is done from the beginning of December to the end of May of the year while harvesting is done from the beginning of November to the end of May (Yersaw, 2011, Sept. 20, Personal interview).

Such classification of periods is done due to mainly rain, which facilitates erosion if the cultivation is not covered by plants when it starts raining and makes harvesting impossible during the three month rain period. As a result, cultivation, and harvesting as well as plant operation will not be undertaken during the rainy season that extends from June to September.

All factories cultivate sugar-cane by irrigation. Wonji- Shoa and Metehara sugar factories employ furrow type irrigation as the topography is flat whereas Fincha, surrounded by hilly landscape, utilize sprinkler type to reduce erosion. These irrigation systems practiced by the factories waste considerable amount of water due to poor management and low level of awareness (Shimeles, 2011, Sept. 20, personal interview). Proper account of water lacks as to what amount of water effectively utilized for

the farm and that part of water being wasted. Water is normally considered by the farms as a free resource despite the fee the factories have to pay to the Ethiopian Water Works Authority, a government body which constructed and owns the irrigation facility (Shimeles, 2011). However, there is no explicit amount that goes only to the water quantity, the payment is as a lump-sum including for the construction.

Use of pesticides and fertilizers are also common to all farms. Since the locations of the farms differ, so does the type of pests on the farm. As a result, the type and quantities of pesticides the plantations apply differ. Generally, insecticides like Malathion and Dursban, herbicides like Glyphosate, Velpar, Paraquat, 2-4D Amine and fungicides like Benomyl, Lysol are being used by the farms. Urea and DAP are also the main fertilizers of the plantations (Shimeles, 2011 and Yersaw, 2011, personal interview).

The current cultivation areas as well as the production quantity of sugar cane are very small compared to the country's potential. The identified potential land area that suits for cultivation of sugar cane has been estimated as 700,000 hectares (MME, 2007). The average cane production per hectare is assumed to be 154 tones, which would deliver a potential sugar cane production of 107.8 million tones.

Realizing this potential and the investment opportunities in the sector, many private investors have shown interest and received investment license. According to the Ethiopian Investment Office (Aklilu, 2011, Oct.



2, personal interview), 20 private (mainly foreign ones) investors have been licensed to develop sugar cane cultivation with a total land area of about 400 hectares. Most of these private actors are at the pre-implementation stage; only 4 of them have received the land they have requested. The exact status and future potential of all the private firms could not be fully captured as they are scattered in the different region and unable to reach them through phones. But at the current position, they don't seem influential and dominant firms in the value chain- though the interest of these private firms and their involvement indicate the bright prospects of the feedstock production and of bio-ethanol development in the country.

#### **4.1.3. Sugar extraction**

The main firms that play a role in the sugar extraction operation today are the existing three sugar factories which are already in operation. Others are in the process of entering into the field. Particularly, Tendaho project is believed to play dominant role when it is completed.

The entire sugar cane that is being cultivated and produced by the sugar factories will be consumed for production of sugar. At the moment, no sugar cane is cultivated solely to the production of bio-ethanol. All sugar cane produced goes to sugar production and the byproduct from the sugar factories, molasses, is utilized for bio-ethanol production. This is because sugar is a high value product in Ethiopia and still there exists a gap between locally produced supply and demand. The general process

flow how the sugar factories convert sugarcane into sugar is shown in fig 3-1 on the next page.

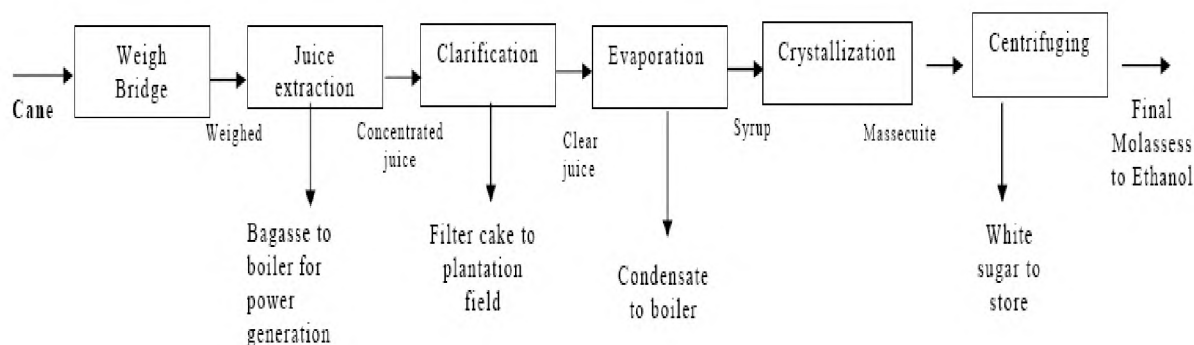


Figure 3-1 - General process flow of Sugarproduction in Ethiopia

Source: Fincha Sugar factory

Sugar cane coming from the field is weighed first and passed to the juice extraction stagewhere separation of juice from bagasse is made. Bagasse is the fibrous residue of the cane stalkafter crushing and extraction of the juice. This bagasse goes to boiler for steam generation tobe used for the sugar factories own consumption. The steam generated is enough to cover thesugar factories thermal energy requirement. They however take additional energy from thenational grid (generated 100% from hydro) to fulfill the electricity requirement except Fincha,which is self-sufficient that require additional electricity only in the winter season formaintenance work as it doesn't have production in the winter and thus doesn't generate energyas the rain makes virtually impossible to cut and transport sugarcane.

All factories have shortterm plan to generate electricity and sell the excess power to the national grid, which was notthat attractive in the past due to low electricity rate.

Then the production process continues with clarification step wherein impurities (scums) areseparated from the juice. These impurities contain generally about 1% in weight of phosphate,counted in  $P_2O_5$ , coming from cane and sometimes also from clarification aids. They alsocontain nitrogen and a great part of proteins existing in cane juice. They havetherefore fertilizing properties and are used on the sugarcane plantation field (Muleta, Yiersawand etal, 2011, personal interview).The clear juice obtained at this stage is further concentratedby evaporation where the condensate is returned to boiler to increase thermal energyefficiency.

Then crystallization (formation of sugar crystals) followed by centrifugation(separation of sugar and molasses) complete the process. The molasses obtained at this finalstage then goes to the production of bio-ethanol. It is residual syrup from which no crystallinesucrose can be obtained following evaporation, crystallization and centrifuging of themassecuite (mixture of sugar crystal and molasses). It is a by-product of sugar manufacturingand the cheapest source of feedstock for ethanol production.

The existing three sugar factories employ the same kind of production step as depicted here-aboveand together currently produce 295,063 tons

of sugar annually (Shimeles, 2011, Sept. 30, Personal interview). The new project which has been launched already with an investment capital of \$600 million is expected to boost the production by 600,000 tonnes, which is expected to start in 2013 (ESC, 2011). With the expansion work being undertaken by the other three factories together, the four state owned factories alone are expected to produce 1,560,981 tons of sugar by the year 2013/14 (ESC, 2011).

The shortage of sugar supply and the attractiveness of the EU market coupled with the annual rising need for sugar certainly call more expansion work and new investment in the sector to come in. This in turn will benefit the production of bio-ethanol by supplying increasing amount of molasses generated from the sugar factories.

#### **4.1.4. Fermentation and distillation processes of bio-ethanol**

There are only two plants, Fincha Sugar Factory and Metehara Sugar Factory, engaged in fermentation and distillation for the production of bio-ethanol to date in Ethiopia. The other state owned factories are in the process of installing an ethanol production unit from molasses following the government direction to introduce a mandatory regime to blend bio-ethanol with gasoline for vehicles fuel. This can render a good option for the factories as they generate huge amount of molasses and be a means to convert into useful products easily.

The Fincha bio-ethanol plant and Metehara are the only plants now producing bio-ethanol, both technical (hydrous) and anhydrous which can

be used for power alcohol. The current annual production capacity of the two factories is 55,962m<sup>3</sup> liters per year (Bekele, 2011, Oct. 8, personal interview).

Wonji-Shoa sugar factory has completed the feasibility study and is now in the bid preparation phase to invite companies to participate in the supply of equipment and erection as well as commissioning of a bio-ethanol plant (ESC, 2011). It is expected as the envisaged plant would start producing bio-ethanol around end the last quarter of 2012.

Likewise, Tendaho sugar Factory project (the biggest in capacity) has awarded a contract to possess a turnkey plant comprised of sugar extraction and bio-ethanol producing plant to an Indian company. The project is in the civil construction and equipment manufacturing phase and the plants are expected to be operational in 2012 (Bekele and Shimeles, 2011).

The potential ethanol production from the 700,000 hectares of suitable irrigable land for sugar cane plantation is estimated as 1 billion liters. The assumptions taken to arrive to this figure are: (1) total net irrigable area identified for sugar cane is 7000,000ha (2) average cane production per hectare as 154 tons (3) percentage of molasses from the total sugar cane produced is 3.8% and (5) Ethanol production per ton of molasses as 250 liters (MME, 2007).

In the next 5 years till 2015, the state owned four sugar factories have planned to reach a production volume of 181 million litres (ESC, 2011).

Though additional quantities are also expected from private firms, reaching those who requested an investment license to enter into the sector was not possible. But it can be assumed as the quantity will be more than the number shown if not reached 1 billion in the short and medium term.

The existing bio-ethanol production plant employs a combination of biological and physical processes in the production. It is produced by fermentation of sugars with yeast and then concentrated to fuel grade by distillation. The flow chart, shown in Fig 3-2 below, is a schematic representation of the principal steps in fuel bio-ethanol production in Ethiopia.

There are three sub units namely Molasses treatment, fermentation and distillation that are carried out in the bio-ethanol production process. These are briefly described below as explained and understood in the site visit.

The first process step in fuel bio-ethanol production is molasses treatment. This stage envisages a reduction in the level of impurities, notably Calcium salts to facilitate the next operations, i.e., fermentation and distillation. This guarantees better performance with regard to distillation where the reduction in scaling will be significant, thus permitting better yields and lower steam consumption (Azemera, 2011, Oct 20, personal interview).

Molasses at a concentration of 860 Brix<sup>30</sup> comes from the sugar factory, undergoes heating to a temperature of 95-100 °C and dilution to 500 Brix using process water and steam condensate in order to reduce molasses viscosity. While heating, acidification is undertaken using sulphuric acid to a pH of 4.7-4.9 and then sent to decanters to remove solid materials by sedimentation. The diluted juice in decanters will be further diluted to a final concentration of 20-220 Brix and cooled to a temperature of 55-60 °C, which is now called as **Mash<sup>31</sup>**. This Mash is now free of large part of the impurities and suitable for obtaining a good fermentation.

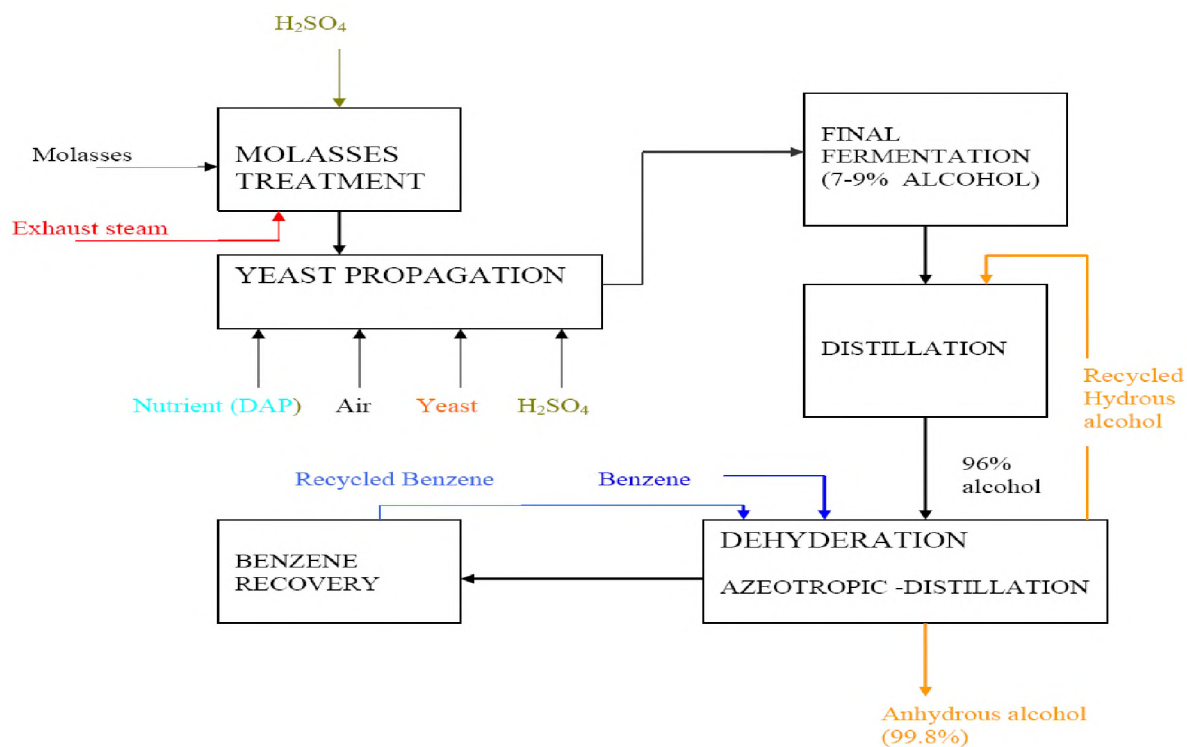


Figure 3-2 Bio-ethanol production process

Source: From Site visit at Fincha Sugar Factory, 2011

Yeast propagation is a pre-fermentation step in the fermentation process aiming to achieve optimum yeast cell concentration required for fermentation. The stage is supplied with nutrients and air and thus the process is referred as aerobic fermentation. The nutrients to be added are nitrogen and phosphorous, due to the fact that the raw material (molasses) is poor in these components for the yeast to multiply and be active. Nitrogen is important both for the phases of cell multiplication and fermentation, mainly because of protein and nucleic acid synthesis. When Nitrogen deficiency occurs, cell growth is reduced and the speed and the productivity of fermentation also decrease. Nitrogen is added in the form of ammonium sulphate. Final fermentation is a process where alcohol and carbon dioxide is produced. The whole fermentation process takes about 24-30 hrs, with resulting beer (fermented mash) containing 7-9% ethanol by volume.

The third step is distillation, in which the fermented beer is distilled to draw off ethanol. By conventional distillation processes ethanol can be concentrated to about 96% ethanol by volume, which is called hydrous ethanol or technical ethanol that is utilized by pharmaceuticals, beverage industries and others. The anhydrous bio-ethanol or bio-ethanol to be used for fuel with gasoline blend should be concentrated and further distillation cannot increase this percentage, as the composition forms an azeotrope, or a constant boiling. The remaining water can be removed by dehydration, a step that follows conventional distillation.



Therefore, aromatic benzene is added to commercial grade bio-ethanol in the dehydration steps so that anhydrous bio-ethanol is obtained. Benzene is chosen due to its less cost compared to other solvents and its consumption is about 1-2 liter per 1000 liter of bio-ethanol. Since the bio-ethanol that has been produced in the past was the hydrous type, benzene consumption was almost none.

The bio-ethanol production of the past shows as the plant was operating at low capacity. As there was no market for anhydrous bio-ethanol both at local and export level, the entire production has been the hydrous type. This figure together with background data is detailed in table 4-3 below. As the conversion of molasses is estimated as 250 liters of bio-ethanol could be obtained from a ton of molasses, there has been excess of it in the past, which the factory was selling for beverage industries and for private cattle farmers to be used as feeds (Azemera, 2011, Oct. 20 personal interview).

## **4.2. Analysis -status and potential**

### **4.2.1. Supply side**

The key factor for determining the economic benefits for Ethiopia for production of bio-ethanol from molasses is the price of molasses for substitute use or products. Ethiopia generates molasses from the sugar factories in significant amount and this quantity is in excess for the local requirement for cattle feed and feedstock for beverage alcohol production. Even the selling price is not attractive; as a result

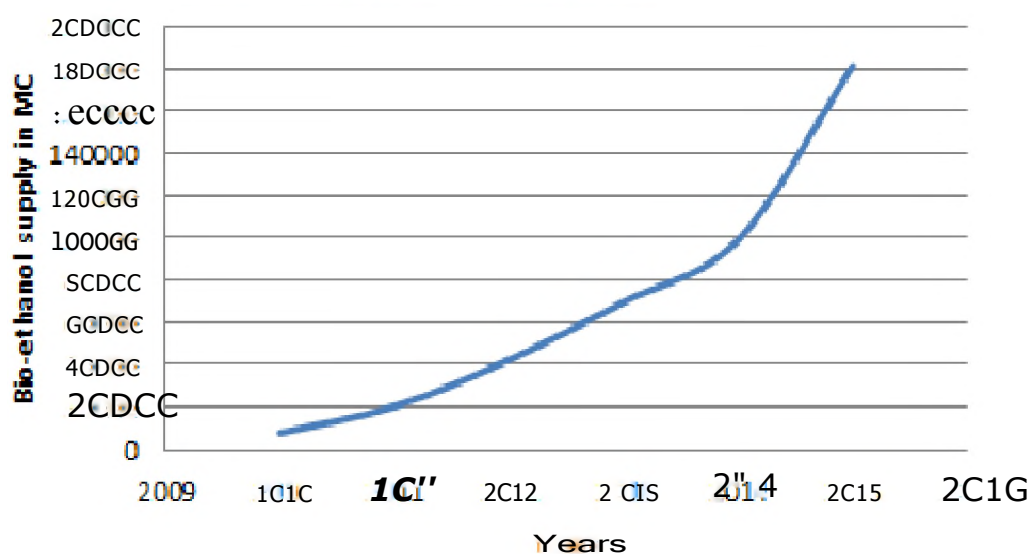
considerable amount of molasses is spoiled during storage or sold at dumping cost (Azemera, 2011). Thus, from supply side production of bio-ethanol for transport fuel use is an opportunity for utilizing the excess molasses. For indication, the following table shows the quantity of molasses and bio-ethanol (both hydrous and anhydrous) expected to be produced in the respective years. It is important to note here that 1 ton of molasses yield about 250 litres of bio-ethanol.

**Table 3-6: Molasses and bio-ethanol production trend**

Description	Years						
	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Molasses (tons)	107,460	165,963	256,534	373,850	466,852	542,559	945,578
Bio-ethanol (liters)	8,482	20,690	55,962	83,452	112,815	132,886	181,604

Source: ESC, 2011

**Fig. 3-1: Planned bio-ethanol production**



#### 4.2.2. Demand side

Currently generally the energy demand of Ethiopia is very low compared to even other least developed countries, consumption stands at 28KWH per capita. This is mainly due to limited access of clean energy by the majority of the population living in the rural areas and underdevelopment of industry as well as infrastructure. However, in order to reduce the poverty level and register steady growth, undoubtedly the demand will increase significantly in the upcoming years. With the expansion of existing and new roads and the on average annual 10% vehicle importation increment (Bazezew, 2011, July 6, personal interview), the demand for transport fuel will also rise. The trend in gasoline requirement as projected by the EPE is shown in the table below.

**Table 3-7: Gasoline Consumption trend**

Description	Years						
	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
<b>Gasoline (M<sup>3</sup>)</b>	20581	231610	243190	255350	268118	281524	295268
<b>Bio-ethanol demand (M<sup>3</sup>)</b>	11029	11,580	11,836	25,801	28,123	30,654	33,413

Source: EPE, 2011

Current gasoline demand is entirely met by imports. If this trend continues to be met, Ethiopia needs to gain access to the heavily

swarmed global demand of gasoline and ensure steady supply to facilitate its growth.

In other words, Ethiopia needs to spend substantial amount of foreign currency to fulfill its gasoline requirement as the trading of petroleum products requires USD or Euro. But this foreign currency payment for petroleum products has already become a heavy burden to the economy of the country, recent report states that around 80% of the foreign earning is consumed by petroleum product imports (Reporter, 2011).

**Table 3-8: Kerosene consumption trend**

Description	Years					
	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
<b>Kerosene in M<sup>3</sup>Qty</b>	<b>295,540</b>	<b>322,139</b>	<b>351,131</b>	<b>382,732</b>	<b>417,178</b>	<b>454,725</b>
<b>Kerosene import cost in billions of Birr</b>	<b>3.6</b>	<b>4.37</b>	<b>4.78</b>	<b>5.21</b>	<b>5.681</b>	<b>5.677</b>
<b>Total cost of petroleum import in billions of Birr</b>	<b>25.89</b>	<b>28.14</b>	<b>30.68</b>	<b>33.46</b>	<b>36.47</b>	<b>39.75</b>
<b>Kerosene import cost %age</b>	<b>13.9%</b>	<b>15.5%</b>	<b>15.58%</b>	<b>15.57%</b>	<b>15.57%</b>	<b>14.26%</b>

Source: EPE, 2011

Thus, with the increasing energy demand, the option to have local source of renewable energy is much attractive.

From the above table, we can see that the cost of kerosene import is on average 15% of the total cost of petroleum import. If Ethiopia starts using bio-ethanol for household energy consumption, there is a potential of replacing kerosene with gasoline which would result in contributing for the saving of about 15% of total cost of foreign currency being used to import petroleum products.

### 3.2.3 Combined View of Bio-ethanol Supply and Demand

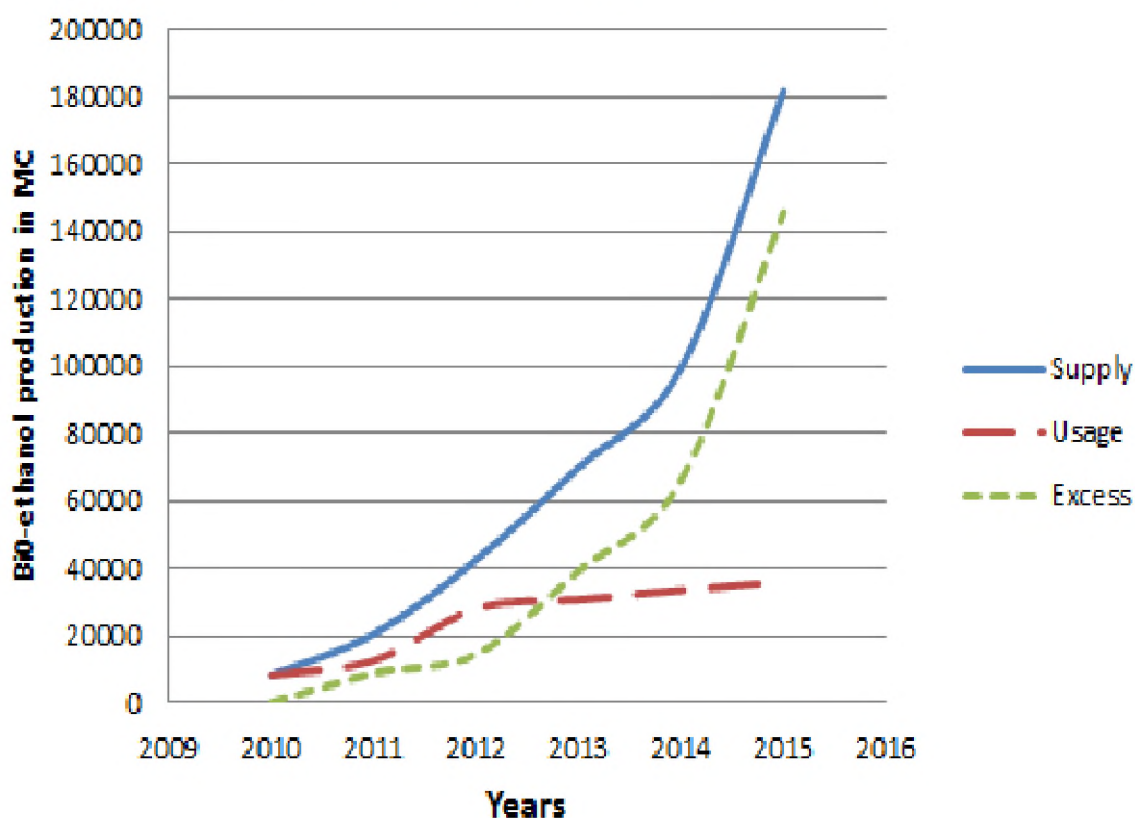
*Table 3-9: Supply and demand of bio-ethanol in M<sup>3</sup>*

Description	Year					
	2009/10	2010/2011	2011/12	2012/13	2013/14	2014/15
<b>Public owned</b>	<b>8482</b>	<b>20,690</b>	<b>55962</b>	<b>83452</b>	<b>112,815</b>	<b>111,204</b>
<b>Private factories</b>						<b>17,600</b>
<b>New projects</b>						<b>52,800</b>
<b>Total Supply</b>	<b>8482</b>	<b>20690</b>	<b>55962</b>	<b>83452</b>	<b>112815</b>	<b>181,604</b>
<b>Planned Gasoline sales</b>		<b>236,706</b>	<b>258,009</b>	<b>281,233</b>	<b>306,541</b>	<b>334,130</b>
<b>Bio-ethanol demand</b>		<b>11,836</b>	<b>25,801</b>	<b>28,123</b>	<b>30,654</b>	<b>33,413</b>
<b>Excess Supply (demand)</b>		<b>8,664</b>	<b>30,161</b>	<b>55,329</b>	<b>82,161</b>	<b>148,191</b>

*Source: ESC, 2011*

As postulated in fig. 3-2 below, up to the end of the fiscal year 2014/2015, the total bio-ethanol production and supply will reach 181.6 million liters. This volume of production and supply will be by far over and above the volume of demand for transport fuel ethanol requirement.

**Fig. 3-4: Excess supply of bio-ethanol**



### 3.2.4 Composition of Gasoline Vehicles

The strategic plan for bio-ethanol development stated that the current proportion of the blend (10% ethanol and 90% gasoline) will gradually increase up to 25% ethanol and 75% gasoline up to 2015. In addition, the strategy indicated that the excess supply of bio-ethanol would be

used for household energy consumption in replacement of kerosene (Ibid).

*Table 3-10: Composition of Gasoline Vehicles by year of manufacture*

<b>Year of Manufacture</b>	<b>Number of Gasoline Vehicles</b>	<b>Number of Diesel Vehicles</b>	<b>Total No. of Vehicles in Ethiopia</b>
Upto 1990	48191	N/A	N/A
1991-2000	62606	N/A	N/A
2001-2010	67821	N/A	N/A
<b>Total</b>	<b>178,618</b>	<b>175,489</b>	<b>354,107</b>

**Source: TAE, 2011**

However, given the current status of the composition (shown in table 3-9) of gasoline vehicles that consume this blend; technically the proportion of ethanol to gasoline cannot go beyond 10% (Manaye, July 13, 2011 personal interview). This is because of the fact that if the percentage of bio-ethanol is to increase beyond 10%, 110,797 gasoline vehicles, which are above 62% of the total gasoline vehicles, should go first through engine modification to make them compatible for a blend above 10%.

Though not that much extensive compared to vehicles made in the years 2000 and before, the recent model vehicles also require some sort of change to adopt them to a blend of bio-ethanol which is more than 10%.

However, the idea of going through engine modification is not yet in the plan of the Transport Authority of Ethiopia. The non-existence of plan to make gasoline vehicles compatible with a blend of above 10% would defeat the strategic plan set-out by the National Biofuel Coordinating Unit to gradually increase the blend up to 25% up to the end of the 5 year GTP period.

In most cases countries use less percentage of blended gasoline for transport fuel such as 5% and 10%. This is due to the fact that less percentage blend doesn't require engine modification (WWI, 2006). In addition, IEA (International Energy Agency) restricted that beyond 10% bio-ethanol content on gasoline cannot be used in all models of gasoline vehicles across the board (IEA, 2009). On the other hand, although starting from the fiscal year just passed (2010/2011) the production of bio-ethanol is in excess of the demand and the efforts to use bio-ethanol for household energy consumption is not likely to materialize in the near future.

This clearly shows that given the excess production and supply of bio-ethanol, it will be a challenge for the sugar industry in particular and of the economy of the country in general. There should be alternative ways to efficiently consume the excess supply for other uses other than transport fuel.



### **3.2.5 Bio-ethanol and Vehicle Compatibility**

It has been stated that in most cases countries use less percentage of blended gasoline for transport fuel such as 5% and 10%. This is due to the fact that less percentage blend doesn't require engine modification (WWI, 2006). More recently research and road test on higher percentages and even on neat bio-ethanol has focused on engine modification in order to use either in higher proportion or entirely run by bio-ethanol (IAE, 2009). In most literature, it is indicated that bio-ethanol blend with gasoline up to 10% doesn't have any problems with the conventional gasoline engine and car manufacturers themselves provide guarantee for this except for old models (IAE, 2009). Many car owners, however, do not know this compatibility and it is on the contrary a concern.

IEA stated the potential problem caused by bio-ethanol-gasoline blend when used on the conventional gasoline operated engine as (IEA, 2004):

**' ... alcohols tend to degrade some types of plastic, rubber and other elastomer components, and, since alcohol is more conductive than gasoline, it accelerates corrosion of certain metals such as aluminum, brass, zinc and lead (Pb). The resulting degradation can damage ignition and fuel system components like fuel injectors and fuel pressure regulators (Otte et al., 2000). As the ethanol concentration of a fuel increases, so does its corrosive effect. When a vehicle is operated on higher concentrations of ethanol, materials that would not normally be affected by gasoline or E10 may degrade in the presence of the more**

***concentrated alcohol. In particular, the swelling and embrittlement of rubber fuel lines and o-rings can, over time, lead to component failure. These problems can be eliminated by using compatible materials, such as Teflon or highly fluorinated elastomers (Vitorns) (EU-DGRD, 2001). Corrosion can be avoided by using some stainless steel components, such as fuel filters...'***

## **CHAPTER FOUR**

### **4. CONCLUSION AND RECOMMENDATION**

#### **4.1. Conclusion**

Bio-ethanol is a fuel derived from biomass sources of feedstock; typically plants such as wheat, sugar beet, corn, straw, and wood. Bio-ethanol is currently made by large-scale yeast fermentation of sugars that are extracted or prepared from crops followed by separation of the bio-ethanol by distillation. One major problem with bio-ethanol production is the availability of raw materials for the production.

The availability of feedstocks for bio-ethanol can vary considerably from season to season and depend on geographic locations. The price of the raw materials is also highly volatile, which can highly affect the production costs of the bioethanol. However, in Ethiopia there is no problem with regards to feedstock for the production of bio-ethanol in the foreseeable future as molasses is being secured in the required quantity from the sugar factories.

Bio-fuels are being promoted in the transportation sector. Many research programs recently focus on the development of concepts such as renewable resources, sustainable development, green energy, eco-friendly process, etc., in the transportation sector. Increasing the use of bio-fuels for energy generation purposes is of particular interest nowadays because they allow mitigation of greenhouse gases, provide

means of energy independence and may even offer new employment possibilities.

Bio-ethanol is by far the most widely used bio-fuel for transportation worldwide. It will continue to be developed as a transport fuel produced in tropical latitudes and traded internationally, for use primarily as a gasoline additive.

From the literature review in chapter 2 and the analysis in chapter 3, we have seen that global production of bio-ethanol increased from 17.25 billion liters in 2000 to over 46 billion liters in 2007. With all of the new government programs in America, Asia, and Europe in place, total global fuel bio-ethanol demand could grow to exceed 125 billion liters by 2020. In 2007, bio-ethanol production represented about 4% of the 1300 billion liters of gasoline consumed globally.

In Ethiopia, bio-ethanol is being produced and used for transport fuel with gasoline at blending mandate of 10%. The country has the potential to increase its production up to 1 billion liters of bio-ethanol in the medium term (5-10 years). It has been identified and portrayed that the production trend of bio-ethanol in Ethiopia has also been increasing. By end of 2015, total supply will hit a record height of 181 million. This would be over and above the projected demand considered for transport fuel.

The country's import requirement of petroleum products is consuming the huge percentage of its foreign currency reserve. Hence substituting

the demand for fossil fuel by locally produced fuels such as bio-ethanol and bio-diesel is paramount importance for the country's economic use of scarce energy resources.

In view of the above summary, the following key findings would answer the questions and address the objectives that have been laid down in this project work in chapter one.

#### **4.1.1. Findings**

This part summarizes the key findings of the research by responding to the research questions laid out in chapter 1 of this project work.

##### ***What is the current status and future potential of bio-ethanol from molasses in Ethiopia?***

Different firms and public bodies involve in the current bio-ethanol endeavor in Ethiopia. The production activity is entirely dominated by sugar factories. There are three sugar factories, Wonji-Shoa, Metehara and Fincha, engaged in sugar production, and the fourth, Tendaho, which will be the biggest in production capacity, is under construction. All the factories cultivate sugarcane for extraction of sugar and they produce or intend to produce Bio-ethanol from molasses, the by-product obtained from the sugar extraction.

It has been pointed out that Ethiopia has 700,000 ha of land suitable for sugarcane cultivation which avails the capacity to produce over 1 billion liters of bio-ethanol. In Ethiopia- the current production capacity stands

at about 55,962 million litres. The other factories are in the process of installing ethanol production units from molasses. In the next 5 years till 2016, they would have the capacity to reach a production volume of 181.6 million litres.

The bio-ethanol production and the requirements for blending with gasoline have been demonstrated and the excess supply has been identified in chapter three.

***How the composition of gasoline vehicles is and what policy measures are required that can help to increase the blend of ethanol with gasoline above 10%?***

Blending with gasoline was started in May 2008 with 5%, and subsequently increased to 10% in March 2011. As the production increases, the intention is to increase the percentage. However, given the current composition of gasoline vehicles, the blend cannot be increased above 10% due to technical restrictions. For the blend to increase above 10%, more than 60% of the vehicles should go through engine modification to make them compatible. It was confirmed that the Transport Authority of Ethiopia has no plan for engine modification in the near future. On the other hand there is no restriction for vehicle import from the point of view of fuel conservation and bio-ethanol usage. There is no incentive either to stimulate the import of new model vehicles.

***What are other possible uses of the bio-ethanol apart from transport fuel?***

Given the Ethiopian context, the other possible use of bio-ethanol is for household energy consumption. The country is using kerosene for household energy consumption especially in the urban areas. This product is supplied 100% from outside through import constituting 15% of the total petroleum import. If the government and other stakeholders expedite the provision for the use of the already excess bio-ethanol supply for household energy consumption, the country would be able to save a huge amount of foreign currency enabling it to reduce the cost of petroleum import at least by 15% in addition to the 10% saving from gasoline import that is being substituted for gasoline.

The usage of bio-ethanol for household consumption has already been envisaged in the strategic plan of bio-fuel development of the country. What it lacks is the identification of appropriate institutional framework and enacting supportive policies.

#### **4.1.2. Recommendations**

In Chapter three parts 3.1 and 3.2 as well as under the key finding of this project work an attempt was made to answer the research questions and address the objectives. This being the main task, the author would also like to supplement some issues that are of significance to the case under study.

Dominant state interventions at the beginning of the development stage of bio-ethanol are important. What needs to be learnt here is that the dominance should not continue forever. It should be for a short period of

time since such activities of the state monopolistic production and market control will be inefficient without the force of competition. For the medium and long term a level playing field should be facilitated for competition.

Provision of tax incentives for vehicle importers to import vehicles that can use higher percentages of bio-ethanol blends will enable higher consumption of bio-ethanol. In addition, there should be a thorough study to come up with a strategic plan that would help to modify the engines of the existing old vehicles in a cost effective means so that they can utilize higher blends of bio-ethanol.

The final and the key recommendation of this project work is for the government to intervene and promote the use of bio-ethanol for household energy consumption in replacement of kerosene by establishing appropriate institutional frameworks and enacting supportive policies. Overarching policies need to be enacted based on thorough studies.

#### **4.1.3. Future Research**

In the opinion of the author, there are a number of areas this study could not investigate sufficiently due to lack of data. These areas require further research.

The first one is the direct and indirect impact of bio-ethanol development on food security. As this involves complex issues to consider, this



research could not come up with clear cut answer. Is the available land suitable to cultivating crop? Can the surface water resource really cultivate 3.7 million hectares? What is the impact of taking 700,000 hectares for sugarcane? What is the potential of sugarcane cultivation to attract individual farmers? Questions of these kinds need to be explored sufficiently to determine the impact of bio-ethanol development on food security.

The second is the energy balance and the net greenhouse gas emissions of bio-ethanol. There has not been any attempt to determine these aspects due to virtually no reliable data. Hence, no information is available to judge the Ethiopian bio-ethanol energy balance and net greenhouse gas emissions. This is an area of research that requires immediate attention to ensure that any development of biofuels is done in a sustainable way.

The third area is the health impact of sugarcane cultivation. The plantations are located in malarial areas and people working there are prone to malaria. In addition sugarcane burning is the normal practice during sugarcane harvest. Such working conditions would not be free from incidents that threaten the health of the workers. Due to the absence of prior studies on the issue, more information could not be provided here. Thus, the author finds the topic an important sustainability aspect from a social point of view.

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## **Appendix I**

### **List of Interviews**

Ahemed A. Sherief (2011) **Personal Communication**, Commercial Manager, National Oil Corporation (NOC), June 8th ,2011

Aklilu Woldemariam. (2011). **Personal Communication**, Director, Investment Promotion & PR Department at the Ethiopian Investment Authority and member of the National Biofuel Committee , Sept 29th 2011.

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